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THE ESTIMATION OF TIME INTERVAL AND ITS RELATION TO PUNCTUALITY.

The Woman's College of the University of North Carolina

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This experimental investigation[2] of time estimation was originally planned to discover a relationship, if any, between (a) recall judgments of visual stimulus duration and (b) rank order of punctuality in classroom attendance on the part of college students.

The tentative hypothesis was entertained that the pattern of recall, in terms of fluctuations as overestimates and underestimates from an accurately measured stimulus referant, would prove to be different for students who had a strong tendency towards tardiness in classroom attendance than for students who were habitually punctual in classroom attendance. If this hypothesis could be verified experimentally, a simple method of sampling time judgments would then be available for the screening of potential latecomers with a view toward correcting faulty time habits.

The investigators were also interested in the possible discovery of statistically significant relationships between scheduled sequences of time judgments as measured in the laboratory and certain facets or dimensions of personality as revealed by scores on the Thurstone temperament schedule, on the Bernreuter personality inventory, on the Otis intelligence test, and from information on personality dynamics obtained in personal interview.

Literature of time estimation.

No attempt is made in this brief report to summarize the research findings in the history of experimental studies on time estimation. Boring (1929 and 1933), Woodrow (1951), and Wallace (1960) have provided comprehensive reviews of research on time estimation carried on in this country and abroad, the latter notably in Germany, France and England. One might mention, however, that during the past decade the interest in the psychology of time has not only increased (perhaps heightened by the "count-down" of the space age) but broadened to the extent that research workers are devoting more time and showing more concern with the relationship between molecular estimation and "macro-events" involving time habits and time orientation through adequate social adjustment. This project haa been planned and directed in part toward a possible discovery of just such a type of relationship.

The appended bibliography contains references which relate either directly or indirectly to the problems which the investigators have encountered during the course of experimentation. The nature of physical time and its relation to methods of measurement and to psychological time (protention) have been covered and dealt with meaningfully by Boring, Dantzig (1937) and Werkmeister (1942). The semantics of time perception and the powerful influence of words in modifying established habits of time have been emphasized by Hayakawa (1941), Jacobson (1948), and Lee (1941). Psychoanalytic and clinical studies on time estimation are numerous: however, reference to any of these studies has been omitted inasmuch as the methods and techniques employed are, for the most part, highly subjective in content, difficult to appraise objectively, and outside of purposes and scope of experimental psychology.

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Experimental subjects.

This investigation utilized the services of 20 female college students (selected from classes in psychology at The Woman's College of the University of North Carolina) as experimental subjects. The first ten subjects were used as "pilots" for the purpose of discovering behavioural attitudes most likely to affect a judgment of stimulus duration. The analysis of the data provided by the pilots led to a redefinition of the term "punctuality," to a revision of the experimental procedures and a different sequence of testing, to the adoption of an unconventional unit of time measurement (0.001 minute), and to the application of a more meaningful statistical design. Approximately 100 hours of experimentation were provided by these pilot subjects.

The second ten experimental subjects were designated as "estimators," and their data constitute the main body of this investigation. The estimators yielded time judgments under experimental conditions of systematic scheduling of four different stimulus durations. Each of the estimators was required to be in attendance at exactly a designated minute within a range of ten minutes before the beginning of each scheduled experimental period. The ability "to be on time" constituted the criterion of punctuality. At the end of the investigation, each subject was ranked in accordance with her ability to meet this criterion. Each estimator gave ten or more hours to experimentation on time estimation, on mental and personality testing, on manual steadiness testing, and on exercises in progressive relaxation.

Places of testing and experimentation.

All tests (intelligence, temperament, personality) and personal interviews were held in one of the laboratory rooms of the department of psychology. All of the pilots and estimators were tested individually and interviewed personally.

All of the controlled experimentation on time estimation was conducted in the sound-proof room (circa 80 db.) located in the basement of the Science Building of the Woman's College of the University of North Carolina. During their experimental work-periods, the estimators were isolated in the sound-proof room. This room is approximately 158 inches long, 125 inches wide and 79½ inches high. All walls, ceiling and floor of this room are shielded to exclude electromagnetic effects or oscillations, and doubly insulated against extraneous sounds, noises and pressure disturbances. Air-conditioning of the room is achieved through a specially designed trap-door vent to a 1 H.P. General Electric Thinline Room Air Conditioner. To maintain room temperature between 72 and 75 degrees F., the conditioner was utilized to circulate fresh cool air for a ten minute period following every 15 or 20 minute period of experimentation. No estimator was permitted to enter the room during the period of air conditioning. Entrance to the sound-proof room is sealed by a heavy door, doubly insulated and shielded. The inside walls and ceiling of the sound-proof room are a dull, neutral gray typical of acoustical insulation. The wall of the room to the right of the entrance is supplied with two portholes through which wires and cables were drawn to effect connections between instruments (heavy duty contact keys) utilized by the pilots and estimators, and the stimulus controls operated by the experimenter in an adjacent laboratory room. After the necessary electrical connections were effected between the two rooms, the portholes were stuffed with soft tissue and absorbent cotton. The means of communication between the subjects and experimenter was controlled through electrical signal devices.

Stimuli used in experimentation with pilots.

1. 3 x 3 mm. square window frosted plastic. Red light and blue light illumination. Forty inches from observer. Background illumination, two 15 watt Westinghouse lamps housed in aluminum reflectors. The reflectors were adjusted to provide even diffusion of light. The red light stimulus was provided with illumination from a monowatt neon lamp. The blue light stimulus was activated by a G.E. 25 watt blue lamp, the intensity of which was reduced to match the red lamp.

2. Stimuli control.

The light stimuli were automatically controlled by 2 Hunter Electronic Interval Timers. The electronic timers were connected to each other in such a way as to provide a constant interval of time between a get-ready signal and the turning-on-and-off of the light stimulus.

3. Stimulus recording

By means of a DPDT 110 A.C. relay placed in circuit with the second interval timer, it was possible to monitor the stimulus to a chronoscope for recording. At the recording table of the experimenter, a neon lamp flashed for the duration of every stimulus presented to the pilot in the sound-proof room.

4. Get-ready signal. A low frequency buzzer of approximately 0.02 sec. duration. This was later changed to a high frequency buzzer for the estimators.

5. Recording of estimators'and pilots'recall judgments of stimulus duration.

Each experimental subject recorded his judgment automatically through manipulation of a contact key which was connected in circuit with the experimenter's chronoscope.

6. Duration periods of stimuli presented to pilots.

   2, 3, 5, 8, 15, and 30 seconds.

Experimentation and findings with pilots.

During the first three weeks of experimentation with the pilots, a number of factors in the sequence of experimental conditions were believed to have influenced the nature and degree of time estimation. The preliminary interrogation, selection and scheduling of experimental subjects into the two categories of punctuality and tardiness in classroom attendance tended to focus undue attention on the purposes of the experimental procedures and thereby invalidate the statistical significance of the time relationships and differences being sought. To state the problem briefly, the sheer awareness of tardiness and its possible relation to an experimental measurement of judgments of stimulus duration had the effect of seriously modifying or even nullifying the meaning of the category into which the subject had orginally classified herself. Of the five experimental subjects who had been classified as being tardy, three subjects stated that they were no longer late for any classes, meals or appointments. Thus tardiness had been eliminated as a factor by the very act of measuring an aspect of time in the laboratory. At the time of this discovery, the decision was made by the experimenters to utilize the first ten subjects as pilots. Pilot subjects made it possible to discover what parts of the experimental procedure to eliminate, what parts to retain, and what improvements in experimental scheduling could be made to eliminate as far as possible any element of fatigue in response on the part of a given subject in judging a succession of stimuli. As a result of working with pilots, the following changes were made in the experimentation with estimators:

1. Estimators were not pre-classified into punctual and tardy subjects.
2. The concepts of "punctuality" and "tardiness" were not introduced into any of the experimental procedures.
3. The investigators retained the concept of "punctuality" in their research, but gave it more operation meaning. The subject demonstrated her punctuality by "being on time." (see page 3, paragraph 2).
4. Stimuli used in experimentation with estimators:

   Red light (Wratten filter No. 70); circular area, 10 mm. diameter, provided by artificial pupil, and seen by estimator at a distance of 96 inches. Source of light, 60 watt Westinghouse Beauty Tone.

   Blue light (Wratten filter No. 49); circular area, 10 mm. diamater, provided by artificial pupil, and seen by estimator at a distance of 96 inches. Source of light, 60 watt Westinghouse Beauty Tone.

To eliminate negative after images or visual aberration in the form of a double or overlapping impression, a thin sheet of frosted plastic film was inserted between the Wratten Filters and the artificial eye. When the lamp was not illuminated, the aperture was seen as light gray by all estimators. The background illumination was the same as for the pilots.

5. Stimuli control: The same as for pilots.
6. Stimulus recording and monitoring: - Same as for pilots, except that a Standard Electric Chronometer replaced the Stoelting Chronoscope which had been used with the pilots.
7. Get-ready-signal. A high frequency buzzer of approximately 0.02 sec. duration replaced the low frequency buzzer used for the pilots.
8. Recording of estimators' judgments of stimulus duration. Same as for pilots, except the Standard Electric Time chronometer measured the duration of the stimulus in 0.001 minute.

9. Unit of time used in measuring recall judgment of stimulus duration: 1/1,000 min.

10. Experimental schedules of stimulus duration.: An experimental schedule consisted of ten stimuli presented in sequential order. Thus, the schedule designated as 20 B means that ten stimuli of blue light each having a physical time duration of 20/1,000 of a minute were presented to an estimator for his recall judgments. The durations used were 20, 40, 80, and 160. These durations were selected for the purpose of discovering possible laws of ratios in time estimation.

In addition to schedules consisting of ten stimuli with each stimulus in the sequence of ten having the same constant duration, two additional types of schedules were introduced to determine the possible existence of illusory stimulus effects on time estimation. One schedule was called A-S-D (ascending-stationary-descending sequence) and consisted of the following durations: 20-40-80-160-160-160-160-80-40-20. The other schedule was called D-S-A (descending-stationary-ascending sequence) and consisted of the following durations: 160-80-40-20-20-20-20-40-80-160. The estimators were never given any information whatsoever concerning the actual durational values of any stimuli presented to them.

In starting a schedule, two short buzzer signals meant "attention." Fifteen seconds following the attention signal, the "get-ready" buzzer signal was given, and from that point the electronic interval timers automatically took over the duty of timing the interval between the get-ready signal and the stimulus as well as the duration of the stimulus. Each estimator made her estimation immediately following the cessation of the stimulus. The interval of waiting to make a recall judgment varied between 0.002 to 0.005 min. for different estimators. A rest of fifteen seconds between the point of judgment cessation and the subsequent get-ready signal permitted the experimenter to observe the position of the pointer on the recording chronometer and copy the recorded time of recall judgment.

Not more than three schedules were given during any single experimental period. Only two schedules of 160 were given during a single period. In table 1, as in the other tables listing time characteristics, the left-hand column gives the 18 schedules presented to each estimator.

11. From an inspection of the data obatined from the pilots during the first five weeks of experimentation, the hunch was entertained that expectation accompanied by some anxiety about the results of judgment led to a perception of shortened time and hence underestimation. Talking with three of the pilots about the nature of their results led them to confess their anxiety and thus to confirm our hunch. From this hunch we went to a second; namely, that release from tension (motor) or, to progressively increased relaxation (motor), would tend to increase the error in the direction of overestimation. Exercises in progressive relaxation were carried out with three pilots to verify this hunch. The results were amazing in support of our hunch. And so the estimators, like the three pilots, were given these

same exercises and taught Jacobson's briefer rules for progressive relaxation. The reader should keep in mind that the data obtained from the estimators (and organized statistically in the appended tables) represent time estimations under the influence of progressive relaxation. The estimators were instructed not to count, not to tense any muscle or muscle groups of the body, not to attend to any bodily rhythms or physiological processes. Winking of the eyelids was inhibited during the periods of stimulation and judgmental response. Attention was directed to the duration of the stimulus (sensory attention) and to the recall image of the stimulus duration (imaginal attention), and not to the minor finger movement (the index and middle finger of the preferred hand) involved in activating the contact key. (see reference 69,pp. 42-43, 80.)

12. A steadiness test (the first five holes in the Stoelting steadiness tester were considered diagnostic: see reference 3, p. 394 for set-up) was administered before the beginning of each experimental period and at the end of each experimental period. The results from the administration of these tests revealed that all of the estimators, with the exception of estimator No. 2, showed a higher level of steadiness with the preferred hand at the end of a period than at the beginning of the period. This manual steadiness test was a means of ascertaining the level of relaxation of the preferred hand used in estimating the duration of a stimulus. Estimator No. 2 was a very tense person. Her anxiety - born of problems in her home and of possible failure in her courses at college - was so severe that she could never get the "feeling" of relaxation for more than a few minutes after relaxing her muscles. At the end of the investigation, she confessed that she worried a lot and that several of her teachers had told her she was "nervous."(!)

13. Avoidance of language in written instructions having associations with time. As several authors of works on semantics have shown, the English language (and perhaps other languages as well) is saturated with words, signs, and symbols connoting time in some form. The use of such words as "depress," "hold," "release," "until," and other similar forms were avoided in describing the function of the contact key. In place of verbal instructions, a demonstration by the experimenter on the proper use of the key was given.

14. Stimulus frame. The stimulus frame consisted of a rectangular piece of heavy, dull-black cardboard measuring 28 inches in height and 22 inches in width, and suspended in a fixed position 53½ inches from its top edge to the floor of the sound-proof room. A circular aperture measuring 20 mm. in diameter, centered 11 inches from either side of the frame and 9 inches from the top of the frame, provided the opening through which the recessed artificial pupil of 10 mm. diameter was plainly visible.

15. Fixation point for peripheral estimation. Color disc, 10 mm. diameter, fixed on edge of stimulus frame, 10 inches from center of artificial pupil. The colors - red and blue - were selected to match light hues of filters.

Statistics. (Experimental Design)

1. Arithmetic mean of unit estimates in each schedule when stimulus duration is a constant throughout schedule (The arithmetic mean in this study is defined as that mathematical point in a sequence of time values above and below which the number of units of variation is the same) (ET in Table 3)
2. Arithmetic mean of unit overestimates in each schedule when stimulus duration is a constant throughout schedule. The referant for overestimation is the stimulus duration of the schedule. (AO in Table 3)
3. Arithmetic mean of unit underestimates in each schedule when stimulus duration is a constant throughout schedule. The referant for underestimation is the stimulus duration of the schedule. (AU in Table 3)
4. The number of correct estimates (estimate equals stimulus duration) in a schedule of 10 stimuli when all stimuli are equal to each other in duration. (C in Table 3)
5. The greatest range of overestimation from the stimulus referant in a schedule of 10 stimuli of equal duration. (RO in Table 3)
6. The greatest range of underestimation from the stimulus referant in a schedule of 10 stimuli of equal duration. (RU in table 3)
7. The frequency of overestimates in each schedule when the stimuli are the same in duration. (fO in Table 3)
8. The frequency of underestimates in each schedule when the stimuli are the same in duration. (fU in Table 3)
9. The arithmetic mean of the middle four unit estimates in an A-S-D sequence compared with the first four and last four unit estimates in a schedule of 10 stimuli of equal duration (160/1,000)
10. The arithmetic mean of the middle four unit estimates in a D-S-A sequence compared with the arithmetic mean of the first four and arithmetic mean of the last four unit estimates in a schedule of 10 stimuli of equal duration (20/1,000).
11. Rank order comparison of estimators in punctuality, in steadiness, and in four different schedules of estimation.
12. An attempt to submit a statement of broad probability concerning a connection between personality and time estimation, and between intelligence and time estimation. The phrase "time estimation" should be interpreted in terms of the specific experimental stimulus duration recall judgment schedules of this investigation.

Summary

Interpretation of statistics.

The most interesting feature to emerge from this research on time estimation is the indeterminate nature of recall judgment in a sequence of judgments constituting a time schedule. By indeterminate, the authors do not mean non-causal, but rather unpredictable. Not only were we unable to predict the level of recall judgment from its antecedent judgment or judgments within a single schedule of time estimation, but we were unable to forecast the pattern of response that characterized one schedule from the pattern of response that was characteristic of a previous similar schedule.

The phenomenon of self-correction for undue overestimation or undue underestimation is worthy of mention. The range of overestimation or underestimation within a single schedule is the limit of cognizance of error in estimation for a given subject. The limit varies greatly not only at points within successive schedules for a given pilot or estimator, but also in a comparative evaluation of the points within the same schedules for all pilots as well as estimators.

In the A-S-D and the D-S-A schedules, the descent, when plotted as a graph, is more rapid while the ascent is slower. It would seem from our data that the expectation error tends to create underestimation in both the descending series and the ascending series.

There is no conclusive evidence that any marked learning takes place in a single schedule when all statistical aspects relating to a single schedule are taken into account.

There does not seem to be any formula or law that can be attributed to recall judgments of duration when the duration stimuli are presented in geometric order.

Just why some estimators were able to estimate more accurately peripherally seen stimuli of a given duration than foveally viewed stimuli of the same duration is not clearly understood. It is clear, however, that the hue seen peripherally by each estimator was described as "different" from the hue seen foveally. We would expect such differences to exist from the previous studies on color perimetry.

While the source of illumination was the same (in watts) for both filters used in this investigation, it should be pointed out, however, that the excitation purity and the luminous transmittance of the two filters were not the same. For the red filter (Wratt no. 70), the dominant wave length was 678.0, the excitation purity 100.0, and the per cent of luminous transmittance 0.68, while for the blue filter (Wratten no. 49) the dominant wave length was 461.0, the excitation purity 98.5, and the luminous transmittance only 0.23. Whether the differences in estimating the duration of these two color stimuli could be attributed in part to the differences in luminous transmittance of the two filters is not clear. The esthetic values and meanings of the two perceived colors, however, may have played an unknown yet important role in time estimation. Estimator No. 7 regarded the red stimulus as "evil" and confessed at the end of the investigation that (quote) "I often thought of the devil when the red light was flashed on." Estimator No. 10 said she "loved the red light" and that it reminded her of beautiful red roses that she once received from a dear friend. Estimator No. 9 said that the blue light stood for the many evenings of romance she had experienced. Subjects in isolation, but not from their thoughts!

When both pilot subjects and estimators (the latter during the final experimental period) were permitted to count or to set up a preferred tapping rate as a criterion for estimating the duration of a given stimulus, their judgments were remarkably accurate when compared with judgments under the influence of muscular relaxation. The following sample for the ten estimators in schedule 80 R will bear out this fact:

	Estimators									
	1	2	3	4	5	6	7	8	9	10
ET	80.6	81.6	80.8	82.0	82.4	81.4	80.4	79.2	81.0	82.2
AO	0.6	1.6	1.2	2.0	2.4	1.6	0.8	0.2	1.0	2.2
AU	0.0	0.0	0.4	0.0	0.0	0.2	0.4	1.0	0.0	0.0

These estimates should be compared with those for the same schedule (80 R) in table 4. A simple inspection reveals the superiority of the above estimates (excepting Estimator No. 10) over the estimates made by the same estimators under the influence of muscular relaxation.

During the final period, when the estimators learned how to estimate stimulus duration by means of a metronome rate of 200 per minute, their estimates of the same stimulus duration was nearly as accurate as a monitoring chronometer. (Subject No. 10, however, had considerable difficulty in shifting from her preferred rate to that of the metronome.).

In his most recent contribution to psychology, Hall (45: p. 156) devotes a total of five lines in his text to the topic of time perception. He states "our perception of time is notoriously bad. That is why we carry watches. There is no built-in time sense in man, nor in any other animal. We perceive that time is passing because of events that take place in time." To Hall's statement we should like to add that recall judgments of stimulus duration at the molecular level are even more notorious for their inaccuracy than perceptions at the same level, especially, as we have found, when motor rhythms are inhibited and the recall judgments are made under the influence of muscular relaxation.

It would seem from our statistics (table 11) that the relationship between the results of four critical schedules of time estimation and level of punctuality is approximately zero. Moreover, there does not seem to be any significant relationship between I.Q. level and accuracy in time estimation. So far as personality is concerned, there is merely a slight hint from our test results that one or more facets as extremes of personality structure may be associated with a greater degree of variability in time estimation. However, in drawing any conclusion of this kind, we are mindful of the low validity of the personality inventories (58; 59).

To the variables which Loehlin (83) recently (1959) assigned through factorial analysis to differences in time estimation, we should like to add tentatively the variable of muscular relaxation. From the analyses of the data of this investigation, it would seem that muscular relaxation functions in a dominant way to interfere with the accuracy to estimate small units of time.

Footnotes

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2. The authors express their thanks to Dr. ~~Kenon~~ Kendon Smith, head of the department of psychology at the Woman's College, for the use of the sound-proof room, chronoscopes, electronic interval-timers, impulse counters, steadiness testers and other equipment to carry out this experimental study on time estimation. The authors also express their appreciation for assistance given and for the many helpful comments and suggestions made by Dr. Kendon Smith and Dr. Robert Radlow concerning the use and application of electronic interval timers to the type of research described in this paper.

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Table I

Intelligence Quotients and Personality Ratings of Pilot Subjects

Subject Number	I.Q. (Otis)	Bernreuter Personality Inventory			
		B1-N	B2-S	B3-I	B4-D
10	119	65	35	58	56
11	117	99	1	99	1
12	121	1	65	11	88
14	116	28	11	24	62
15	113	19	83	15	86
16	108	88	9	79	12
17	108	21	81	27	83
18	133	43	45	46	58
19	120	49	9	38	27

TABLE 2

Intelligence Quotients and Personality Profiles of Experimental Subjects

Subject Number	I.Q. (Otis)	Bernreuter Inventory				Thurstone Temperament Schedule						
		B1-N	B2-S	B3-I	B4-D	A	V	I	D	E	S	R
1	112	12	83	21	95	19	61	75	99	82	94	61
2	121	65	11	50	43	63	88	37	48	21	74	50
3	115	73	2	68	39	19	6	27	97	2	62	71
4	131	41	14	29	62	84	61	27	71	30	62	18
5	125	5	67	5	81	75	61	37	77	94	50	61
6	131	1	88	5	99	51	72	83	97	66	74	50
7	105	71	3	62	15	29	39	1	15	21	29	18
8	108	97	1	83	4	41	72	83	28	48	74	61
9	122	67	3	54	52	75	99	91	87	30	99	61
10	125	12	98	30	93	98	72	62	87	30	74	93

(Legend for Table 3)

Statistical aspects of time estimation. Stimulus - blue light, artificial pupillary diameter 10 mm. at 96 inches. Duration of stimulus - 0.040 minute. Type of estimation - peripheral. Each figure in this table is represented by a schedule of 10 stimuli for time estimation. The symbols in this table have the following meanings: Est stands for the individual estimators numbered from 1 to 10; ET is the average time of estimation; AO is the average time of overestimation; RO is the range of overestimation; fO is the frequency of overestimation; AU is the average of underestimation; RU is the range of underestimation; fU is the frequency of underestimation; C is the frequency of correct judgments of time.

Table 3

Est	1	2	3	4	5	6	7	8	9	10
ET	36.1	34.1	35.0	36.2	37.3	40.3	40.5	30.7	39.8	35.9
AO	0.0	0.3	0.0	2.1	0.5	1.9	2.4	0.0	2.8	0.2
RO	0-0	0-3	0-0	0-14	0-3	0-8	0-12	0-0	0-17	0-1
fO	0	1	0	3	3	6	5	0	6	2
AU	3.9	6.2	5.0	5.9	3.2	1.6	1.9	9.3	3.0	4.3
RU	0-8	0-11	0-12	0-19	0-8	0-12	0-7	0-13	0-15	0-10
fU	9	9	10	7	7	2	5	10	4	8
C	1	0	0	0	0	2	0	0	0	0

(Legend for Table 4)

The average performance of each experimental estimator on 18 different schedules. The numbers in the top row extending from 1 to 10 designate individually the ten experimental estimators. The lefthand column of figures headed by the word "time" gives the durational values (in thousandths of a minute) of the several kinds of visual stimuli presented for time-estimation. Thus, 20 B means a schedule 10 successive stimuli of blue light, each stimulus in the schedule having a measured duration of 0.020 minute. The letter R after a figure means that the stimulus was one of red light. The letter P prefixed to a color symbol means that the stimulus activated the periphery of the retina. Stimuli not designated by the letter P activated the fovea of the retina. The quality, intensity and extensity of stimulation were kept constant throughout each schedule for every estimator.

Table 4

	1	2	3	4	5	6	7	8	9	10
20 B	18.4	20.7	23.0	21.8	17.3	24.1	19.7	19.8	25.8	20.3
20 R	20.0	19.9	25.1	18.6	21.8	22.4	21.2	24.4	24.1	23.3
20 PB	22.1	18.7	24.9	21.8	18.8	24.2	20.1	21.1	20.5	17.8
20 PR	20.4	22.3	24.5	19.7	22.9	20.5	20.6	24.1	28.6	23.9
40 B	37.4	33.6	51.2	35.3	42.8	46.2	41.2	31.8	41.5	42.4
40 R	35.7	33.5	42.7	53.3	46.5	44.8	44.9	42.7	36.2	45.7
40 PB	36.1	34.1	35.0	36.2	37.3	40.3	40.5	30.7	39.8	35.9
40 PR	30.7	34.7	39.9	34.1	43.8	48.0	36.6	41.0	43.7	42.3
80 B	74.4	52.3	85.3	62.2	80.6	81.9	92.2	60.4	76.2	75.6
80 R	65.3	60.4	91.0	88.5	85.4	82.7	89.2	64.2	71.3	80.5
80 PB	56.0	58.0	59.3	77.9	79.0	74.2	81.5	40.7	73.4	80.8
80 PR	57.3	80.7	74.3	80.4	86.8	76.4	84.2	79.2	103.8	86.1
160 B	113.5	90.1	121.0	118.8	171.3	147.5	102.2	132.9	88.2	151.4
160 B^1	113.9	90.7	105.3	147.4	163.2	163.2	130.1	108.5	117.7	156.6
160 R	121.4	111.1	123.5	152.4	168.1	160.7	176.0	90.0	181.3	174.0
160 R^1	147.9	123.8	97.7	174.1	158.8	159.7	181.3	119.7	170.4	177.9
160 PB	132.4	124.7	142.0	155.4	167.6	154.9	167.0	72.6	135.3	160.6
160 PR	137.3	131.7	85.5	146.5	161.1	160.5	157.9	133.7	195.6	160.6

PB - Peripheral Blue

PR - Peripheral Red

(Legend for Table 5)

Average of overestimation to average of underestimation in estimators' time-judgments for 18 different schedules. The figure in the numerator is the average of overestimated time, while the figure in the deniminator is the average of underestimated time in each schedule of 10 judgments. The individual estimators are identified by the top row of numbers extending from 1 to 10.

Table 5

Estimators

	1	2	3	4	5	6	7	8	9	10
20 B	$\frac{0.7}{2.3}$	$\frac{1.0}{0.3}$	$\frac{3.3}{0.3}$	$\frac{2.1}{0.3}$	$\frac{0.1}{2.8}$	$\frac{4.6}{0.5}$	$\frac{0.4}{0.7}$	$\frac{0.6}{0.8}$	$\frac{6.2}{0.4}$	$\frac{1.7}{1.4}$
20 PB	$\frac{3.0}{0.9}$	$\frac{0.4}{1.7}$	$\frac{5.1}{0.2}$	$\frac{2.4}{0.6}$	$\frac{0.2}{1.4}$	$\frac{4.3}{0.1}$	$\frac{0.8}{0.7}$	$\frac{1.4}{0.3}$	$\frac{2.5}{2.0}$	$\frac{0.0}{2.2}$
20 R	$\frac{0.7}{0.7}$	$\frac{1.0}{1.1}$	$\frac{5.1}{0.0}$	$\frac{0.3}{1.7}$	$\frac{1.8}{0.0}$	$\frac{2.6}{0.2}$	$\frac{1.5}{0.3}$	$\frac{4.6}{0.2}$	$\frac{4.3}{0.2}$	$\frac{3.7}{0.4}$
20 PR	$\frac{2.5}{2.1}$	$\frac{2.6}{0.3}$	$\frac{4.7}{0.2}$	$\frac{0.5}{0.8}$	$\frac{3.2}{0.3}$	$\frac{1.0}{0.5}$	$\frac{1.1}{0.5}$	$\frac{4.1}{0.0}$	$\frac{8.9}{0.3}$	$\frac{3.9}{0.0}$
40 B	$\frac{2.1}{4.7}$	$\frac{0.7}{7.1}$	$\frac{11.6}{0.4}$	$\frac{1.9}{6.6}$	$\frac{3.3}{0.5}$	$\frac{6.3}{0.1}$	$\frac{2.9}{1.7}$	$\frac{0.0}{8.2}$	$\frac{4.5}{3.0}$	$\frac{3.0}{0.6}$
40 PB	$\frac{0.0}{3.9}$	$\frac{0.3}{6.2}$	$\frac{0.0}{5.0}$	$\frac{2.1}{5.9}$	$\frac{0.5}{3.2}$	$\frac{1.9}{1.6}$	$\frac{2.4}{1.9}$	$\frac{0.0}{9.3}$	$\frac{2.8}{3.0}$	$\frac{0.2}{4.3}$
40 R	$\frac{0.0}{4.3}$	$\frac{0.0}{6.5}$	$\frac{4.5}{1.8}$	$\frac{0.3}{7.0}$	$\frac{6.5}{0.0}$	$\frac{4.8}{0.0}$	$\frac{5.4}{0.5}$	$\frac{3.5}{0.8}$	$\frac{0.5}{4.3}$	$\frac{5.7}{0.0}$
40 PR	$\frac{0.5}{9.8}$	$\frac{0.0}{5.3}$	$\frac{1.3}{11.4}$	$\frac{0.2}{6.1}$	$\frac{5.0}{1.2}$	$\frac{8.0}{0.0}$	$\frac{0.6}{4.0}$	$\frac{1.9}{0.9}$	$\frac{4.3}{0.6}$	$\frac{3.3}{1.0}$
80 B	$\frac{1.5}{7.1}$	$\frac{0.0}{27.7}$	$\frac{7.8}{2.5}$	$\frac{1.0}{18.8}$	$\frac{2.9}{2.3}$	$\frac{4.2}{2.3}$	$\frac{13.0}{0.8}$	$\frac{0.0}{19.6}$	$\frac{2.0}{5.8}$	$\frac{0.6}{5.0}$
80 PB	$\frac{0.0}{24.0}$	$\frac{0.0}{22.0}$	$\frac{0.0}{20.7}$	$\frac{4.2}{6.3}$	$\frac{1.1}{2.1}$	$\frac{0.2}{6.0}$	$\frac{3.5}{2.0}$	$\frac{0.0}{39.3}$	$\frac{2.1}{8.7}$	$\frac{3.2}{2.4}$
80 R	$\frac{0.1}{14.8}$	$\frac{0.0}{19.6}$	$\frac{12.4}{1.4}$	$\frac{14.2}{5.7}$	$\frac{6.8}{1.4}$	$\frac{4.3}{1.6}$	$\frac{9.6}{0.4}$	$\frac{0.9}{16.7}$	$\frac{1.1}{9.8}$	$\frac{1.7}{1.2}$
80 PR	$\frac{0.0}{22.7}$	$\frac{8.0}{7.3}$	$\frac{4.4}{10.1}$	$\frac{6.2}{5.8}$	$\frac{8.0}{1.2}$	$\frac{0.2}{3.8}$	$\frac{5.5}{1.3}$	$\frac{6.1}{6.9}$	$\frac{23.9}{0.1}$	$\frac{6.6}{0.5}$
160 B	$\frac{0.0}{46.5}$	$\frac{0.0}{69.9}$	$\frac{0.0}{39.0}$	$\frac{0.0}{41.2}$	$\frac{11.8}{0.5}$	$\frac{3.7}{16.2}$	$\frac{0.0}{57.8}$	$\frac{11.2}{38.3}$	$\frac{0.0}{71.8}$	$\frac{1.7}{10.3}$
160 B^1	$\frac{0.0}{46.1}$	$\frac{0.0}{69.3}$	$\frac{0.0}{54.7}$	$\frac{10.0}{22.6}$	$\frac{8.1}{4.9}$	$\frac{9.5}{6.3}$	$\frac{0.0}{29.9}$	$\frac{0.0}{51.5}$	$\frac{0.0}{42.3}$	$\frac{2.6}{6.0}$
160 PB	$\frac{1.0}{28.6}$	$\frac{0.0}{35.3}$	$\frac{0.9}{18.9}$	$\frac{6.8}{11.4}$	$\frac{11.8}{4.2}$	$\frac{1.2}{6.3}$	$\frac{10.2}{3.2}$	$\frac{0.0}{87.4}$	$\frac{0.3}{25.0}$	$\frac{5.8}{5.2}$
160 R	$\frac{0.2}{38.8}$	$\frac{0.0}{48.9}$	$\frac{0.0}{37.0}$	$\frac{12.3}{19.9}$	$\frac{8.6}{0.5}$	$\frac{4.1}{3.4}$	$\frac{17.5}{1.5}$	$\frac{0.0}{70.0}$	$\frac{30.4}{9.1}$	$\frac{22.0}{8.0}$
160 R^1	$\frac{8.6}{20.7}$	$\frac{0.0}{36.2}$	$\frac{0.0}{62.3}$	$\frac{18.1}{4.0}$	$\frac{3.0}{4.2}$	$\frac{4.1}{4.4}$	$\frac{24.8}{3.5}$	$\frac{3.0}{43.3}$	$\frac{17.0}{6.6}$	$\frac{21.0}{3.1}$
160 PR	$\frac{1.8}{24.5}$	$\frac{3.4}{31.7}$	$\frac{0.0}{74.5}$	$\frac{7.2}{20.7}$	$\frac{3.9}{2.8}$	$\frac{3.5}{3.0}$	$\frac{3.8}{5.9}$	$\frac{3.4}{29.7}$	$\frac{35.6}{0.0}$	$\frac{8.4}{7.8}$

(Legend for Table 6)

Frequency of overestimation to frequency of underestimation in estimators' time-judgments for 18 different schedules. The numerator in the statement 2/8 stands for the number of times estimator No. 1 overestimated the duration of the stimulus 20 B, while the number in the denominator stands for the number of times estimator No. 1 underestimated the duration of the stimulus 20 B. All ratios in this table, relative to their proper estimators, are to be interpreted in this manner. The individual estimators are identified by the top row of numbers extending from 1 to 10.

Table 6

Estimators

	1	2	3	4	5	6	7	8	9	10
20 B	2/8	5/2	8/2	6/1	1/7	9/1	3/5	3/6	9/1	3/4
20 PB	6/4	3/5	8/1	6/2	1/8	9/1	3/3	7/2	4/3	0/5
20 R	3/5	3/6	10/0	2/6	7/0	7/1	7/1	8/1	8/1	8/1
20 PR	5/5	8/2	9/1	4/3	8/1	6/1	5/2	9/0	9/1	9/0
40 B	2/7	1/9	9/1	4/5	7/2	9/1	5/4	0/10	5/4	7/2
40 PB	0/9	1/9	0/10	3/7	3/7	6/2	5/5	0/10	6/4	2/8
40 R	0/8	0/9	5/4	1/7	9/0	9/0	8/2	6/3	2/7	10/0
40 PR	1/9	0/9	4/5	1/7	9/1	10/0	2/8	5/4	7/3	5/4
80 B	4/6	0/10	7/3	2/8	3/5	5/4	8/2	0/10	4/5	1/9
80 PB	0/10	0/10	0/10	4/4	3/5	1/8	7/3	0/10	2/8	3/5
80 R	1/9	0/10	7/3	5/5	7/3	7/2	7/2	1/9	2/8	7/2
80 PR	0/10	6/4	4/6	5/5	8/2	2/7	8/1	4/6	9/1	9/1
160 B	0/10	0/10	0/10	0/10	9/1	3/7	0/10	1/9	0/10	2/8
160 B^1	0/10	0/10	0/10	3/6	5/5	6/4	0/10	0/10	0/10	4/6
160 PB	1/9	0/10	1/9	3/7	5/5	3/7	8/2	0/10	1/9	3/6
160 R	1/9	0/10	0/10	5/5	8/2	4/6	9/1	0/10	7/3	6/4
160 R^1	3/7	0/10	0/10	7/2	4/6	4/5	8/2	1/9	7/3	8/2
160 PR	1/9	1/8	0/10	3/7	5/5	4/4	4/5	1/9	10/0	5/5

(Legend for Table 7)

Each estimator's range of deviation from the stimulus time in 18 different schedules. The figure in the numerator is the estimator's greatest overestimation in a schedule of 10 judgments, while the figure in the denominator is the estimator's greatest underestimation in the same schedule. The unit of deviation is 0.001 minute.

Table 7

	Estimators									
	1	2	3	4	5	6	7	8	9	10
20 B	5/5	3/2	7/2	2/3	1/8	10/5	2/3	3/2	13/4	8/8
20 PB	10/4	2/8	15/2	6/4	2/3	8/1	4/3	3/2	8/10	0/5
20 R	5/3	7/4	12/0	2/5	4/0	5/2	5/3	9/2	11/2	10/4
20 PR	10/6	6/2	8/2	2/5	6/3	2/5	4/3	8/0	18/3	10/0
40 B	14/10	7/20	22/4	9/15	9/3	12/1	8/7	0/12	28/12	7/4
40 PB	0/8	3/11	0/12	14/19	3/8	8/12	12/7	0/13	17/15	1/10
40 R	0/10	0/14	19/7	3/19	15/0	9/0	15/4	14/3	3/11	11/0
40 PR	5/23	0/10	5/4	2/15	13/12	14/0	5/10	10/5	11/3	10/4
80 B	6/21	0/45	23/14	9/41	12/8	18/11	31/6	0/40	10/14	6/9
80 PB	0/33	0/37	0/46	20/28	7/8	2/13	10/10	0/49	14/18	19/8
80 R	1/26	0/34	57/7	64/20	18/10	15/10	24/2	9/34	9/22	6/9
80 PR	0/34	24/32	24/32	17/19	22/9	1/11	12/13	25/28	57/1	23/5
160 B	0/62	0/95	0/70	0/75	25/5	23/49	0/84	112/55	0/103	11/22
160 B^1	0/61	0/97	0/72	49/78	28/30	25/25	0/52	0/92	0/74	14/22
160 PB	10/59	0/50	9/57	35/32	35/25	8/18	26/22	0/114	3/56	48/21
160 R	2/68	0/78	0/62	47/72	26/3	15/12	38/15	0/111	96/44	119/30
160 R^1	45/50	0/67	0/99	80/30	13/26	26/14	60/20	30/76	46/44	79/22
160 PR	18/64	34/61	0/95	40/52	21/11	22/18	20/30	34/46	56/0	39/32

(Legend for Table 8)

Number of correct judgments of time made by each estimator in each of the eighteen different schedules. The numbers in the top row identify the estimators individually. The schedules are indicated in the extreme lefthand column. Each schedule for each estimator consisted of ten judgments of a given colored light stimulus of specific, constant duration. For the meanings of the symbols B, R, PB and PR, see legend of Table 1.

Table 8

	Estimators									Total for Group
	1	2	3	4	5	6	7	8	9	10	
20 B	0	3	0	3	2	0	2	1	0	3	14
20 PB	0	2	1	2	1	0	4	1	3	5	19
20 R	2	1	0	2	3	2	2	1	1	1	15
20 PR	0	0	0	3	1	3	3	1	0	1	12
40 B	1	0	0	1	1	0	1	0	1	1	6
40 PB	1	0	0	0	0	2	0	0	0	0	3
40 R	2	1	1	2	1	1	0	1	1	0	10
40 PR	0	1	1	2	0	0	0	1	0	1	6
80 B	0	0	0	0	2	1	0	0	1	0	4
80 PB	0	0	0	2	2	1	0	0	0	2	7
80 R	0	0	0	0	0	1	1	0	0	1	3
80 PR	0	0	0	0	0	1	1	0	0	0	2
160 B	0	0	0	0	0	0	0	0	0	0	0
160 B^{1}	0	0	0	1	0	0	0	0	0	0	1
160 PB	0	0	0	0	0	0	0	0	0	1	1
160 R	0	0	0	0	0	0	0	0	0	0	0
160 R^{1}	0	0	0	1	0	1	0	0	0	0	2
160 PR	0	1	0	0	0	2	1	0	0	0	4
Totals	6	9	3	19	13	15	15	6	7	16	109

(Legend for Table 9)

Comparison of individual average time of estimation for the first four and last four (End-4) unit estimates in two separate schedules - blue and red-light stimuli centered for foveal vision at 0.020 min. duration. The extreme lefthand column lists the numbers assigned to the individual estimators. The column headed by the abbreviation "Dscnd" gives the individual average time of estimation for the middle four unit estimates in the descending-stationary-ascending schedule.

Table 9

E s t	Blue Stimulus			Red Stimulus		
	1st-4	End-4	Dscnd	1st-4	End-4	Dscnd
1	20.8	16.8	19.0	19.8	20.8	16.5
2	20.8	20.8	19.8	21.5	19.0	19.0
3	20.8	24.8	20.5	24.5	25.5	26.5
4	21.8	21.5	15.3	19.5	17.0	20.5
5	15.3	18.3	19.5	23.0	23.0	20.8
6	22.8	24.8	26.0	20.8	23.5	18.2
7	19.8	19.8	20.0	20.3	21.0	19.8
8	20.3	19.0	21.0	26.3	22.5	22.3
9	22.5	30.3	20.5	22.0	24.5	20.0
10	18.5	21.5	18.8	22.0	25.3	25.8

(Legend for Table 10)

Comparison of individual average time of estimation for the first four and last four (End-4) unit estimates in four separate schedules - blue and red-light stimuli centered for foveal vision (designated by the letters B and R in the table) at 0.160 min. duration. The extreme lefthand column lists the numbers assigned to the individual estimators. The column headed by the abbreviation "Ascnd" gives the individual average time of estimation for the middle four unit estimates in the ascending-stationary-descending schedule.

Table 10

Est		I		II		III
		1st-4	End-4	1st-4	End-4	Ascnd
1	B	108.0	113.8	118.5	110.5	148.0
	R	108.0	138.0	146.0	149.3	119.0
2	B	80.0	98.5	83.3	110.8	80.7
	R	119.3	107.3	117.5	118.0	156.3
3	B	103.5	138.5	99.3	109.3	153.5
	R	128.0	122.0	104.5	88.5	134.8
4	B	115.3	131.0	135.8	168.3	121.3
	R	120.3	187.0	165.0	179.8	108.0
5	B	165.0	180.3	159.5	171.8	156.8
	R	161.0	176.5	161.3	163.3	152.5
6	B	136.3	157.8	160.0	164.8	167.2
	R	152.8	167.8	166.3	153.0	164.5
7	B	92.3	110.5	119.8	141.5	133.0
	R	170.0	180.5	193.0	170.3	132.5
8	B	153.5	122.3	125.5	89.8	120.8
	R	66.3	104.5	118.3	138.8	91.8
9	B	73.8	89.8	107.5	131.0	61.0
	R	163.3	189.5	166.8	163.5	112.3
10	B	154.8	144.5	162.3	153.5	170.0
	R	140.0	202.3	188.0	174.3	147.3

(Legend for Table 11)

Unit time-judgments given to the blue-light stimulus when scheduled in a descending-stationary-ascending durational order. The numbers in the top row extending from 1 to 10 designate individually the ten experimental estimators. The lefthand column of figures headed by the word "time" gives the durational values (in thousandths of a minute) of the visual stimulus.

Table 11

	1	2	3	4	5	6	7	8	9	10
160	119	113	123	139	155	168	198	55	158	153
80	64	55	53	39	84	71	61	28	79	84
40	25	38	26	23	44	44	32	19	20	38
20	17	17	18	10	22	27	24	23	11	16
20	11	24	21	18	18	29	18	20	25	18
20	26	20	22	12	20	25	20	17	26	21
20	22	18	21	21	18	23	18	24	20	20
40	35	41	42	44	48	52	36	26	53	43
80	75	68	81	75	89	72	82	58	81	85
160	132	122	154	137	161	171	136	142	138	149

Blue-Descending

(Legend for Table 12)

Unit time-judgments given to the red-light stimulus when scheduled in a descending-stationary-ascending durational order. The numbers in the top row extending from 1 to 10 designate individually the ten experimental estimators. The lefthand column of figures headed by the word "time" gives the durational values (in thousandths of a minute) of the visual stimulus.

Table 12

	1	2	3	4	5	6	7	8	9	10
160	132	95	128	175	145	193	172	106	218	224
80	38	63	59	84	72	90	48	58	44	77
40	30	24	36	42	44	35	28	34	34	49
20	15	18	22	20	22	16	20	28	16	30
20	15	18	33	22	22	19	21	21	24	22
20	16	24	20	25	18	17	21	20	16	27
20	20	16	31	15	21	21	17	20	24	24
40	25	28	35	34	40	50	38	29	50	41
80	55	41	72	65	82	96	86	52	108	85
160	87	105	132	123	168	174	165	100	129	189

Red-Descending

(Legend for Table 13)

Unit time-judgments given to the blue-light stimulus when scheduled in an ascending-stationary-descending durational order. The numbers in the top row extending from 1 to 10 designate individually the ten experimental estimators. The lefthand column of figures headed by the word "time" gives the durational values (in thousandths of a minute) of the visual stimulus.

Table 13

	1	2	3	4	5	6	7	8	9	10
20	35	4	20	11	22	21	15	18	17	14
40	48	26	38	40	40	52	28	29	35	42
80	74	62	81	82	81	90	51	51	52	76
160	124	87	190	115	136	175	111	144	80	159
160	142	79	136	141	158	198	151	144	40	164
160	116	64	155	87	168	156	177	87	60	172
160	210	93	133	142	165	140	93	108	64	185
80	82	24	46	81	75	99	76	47	30	75
40	40	23	48	23	39	60	22	29	22	35
20	36	13	25	22	18	28	14	15	16	16

Blue-Ascending

(Legend for Table 14)

Unit time-judgments given to the red-light stimulus when scheduled in an ascending-stationary-descending durational order. The numbers in the top row extending from 1 to 10 designate individually the ten experimental estimators. The lefthand column of figures headed by the word "time" gives the durational values (in thousandths of a minute) of the visual stimulus.

Table 14

	1	2	3	4	5	6	7	8	9	10
20	30	20	23	22	15	15	22	20	15	23
40	31	38	39	43	37	55	42	29	43	30
80	65	69	93	110	74	96	82	51	75	80
160	94	158	162	110	150	162	162	98	106	152
160	120	172	149	98	152	166	125	50	125	156
160	68	172	154	110	148	152	118	125	96	131
160	194	123	74	114	160	178	125	94	122	150
80	45	37	104	64	62	69	61	53	87	83
40	22	24	42	29	43	53	52	38	21	33
20	32	11	28	16	26	26	22	18	17	21

Red-Ascending

(Legend for Table 15)

Rank order of estimators in average punctuality (P), in average manual steadiness (S), and in average time estimation of the shortest and longest visual stimuli. Column W designates rank order of the individual estimators (identifiable by the arabic numerals in the table) in average response to a schedule of ten 0.020 min. red-light stimuli; column X designates rank order of estimators in average response to a schedule of ten 0.020 min. blue-light stimuli; column Y designates rank order of estimators in average response to a schedule of ten 0.160 min. red-light stimuli; and column Z designates rank order of estimators in average response to a schedule of ten 0.160 min. blue-light stimuli. The reader should keep in mind that the arabic numbers are not ranks. The ranking of the individual estimators (whose identity is by number) is in terms of a letter scale extending from A through K. Of the ten possible ranks, A stands for the highest rank or best level of achievement, while K stands for the lowest rank or poorest level of achievement.

Table 15

Rank	P	S	W	X	Y	Z
A	1	4	1	8	6	10
B	6	1	2	7	4	5
C	5	6	7	10	5	6
D	3	5	5	2	10	8
E	4	7	4	1	7	3
F	2	10	6	4	9	4
G	10	9	10	5	3	1
H	7	3	9	3	1	7
J	9	8	8	6	2	2
K	8	2	3	9	8	9

(ABSTRACT of Report to the Woman's College Research Council on Project No. 40)

THE ESTIMATION OF TIME INTERVAL AND ITS RELATION TO PUNCTUALITY

The Woman's College of the University of North Carolina

Julia H. Heinlein and Christian Paul Heinlein

This experimental investigation of time estimation was originally planned to discover a relationship, if any, between (a) recall judgments of visual stimulus duration and (b) rank order of punctuality in classroom attendance on the part of college students.

The tentative hypothesis was entertained that the pattern of recall, in terms of fluctuations as overestimates and underestimates from an accurately measured stimulus referent, would prove to be different for students who had a strong tendency towards tardiness in classroom attendance than for students who were habitually punctual in classroom attendance. If this hypothesis could be verified experimentally, a simple method of sampling time judgments would then be available for the screening of potential latecomers with a view toward correcting faulty time habits.

The investigators were also interested in the possible discovery of statistically significant relationships between scheduled sequences of time judgments as measured in the laboratory and certain facets or dimensions of personality as revealed by scores on the Thurstone Temperament Schedule, on the Bernreuter Personality Inventory, on the Otis Intelligence Test, and from information on personality dynamics obtained in personal interview.

This investigation utilized the services of 20 female college students (selected from classes in psychology at The Woman's College of the University of North Carolina) as experimental subjects. The first ten subjects were used as "pilots" for the purpose of discovering behavioural attitudes most likely to affect a judgment of stimulus duration. The analysis of the data provided by the pilots led to a redefinition of the term "punctuality," to a revision of the experimental procedures, to a more efficient sequence of personality and intelligence testing, to the adoption of an unconventional unit of time measurement (0.001 minute), and to the application of a more meaningful statistical design. Approximately 100 hours of experimentation were provided by these pilot subjects.

The second ten experimental subjects were designated as "estimators," and their data constitute the main part of this investigation. The estimators yielded time judgments under experimental conditions of systematic scheduling of four different stimulus durations (0.20, 0.40, 0.80, and 0.160 min.). Each of the estimators was required to be in attendance at exactly a designated minute within a range of ten minutes before the beginning of each scheduled experimental period. The ability "to be on time" constituted the criterion of punctuality. At the end of the investigation, each subject was ranked in accordance with her ability to meet this criterion. Each estimator gave ten or more hours to experimentation on time estimation, on mental and personality testing, on manual steadiness testing, and on exercises in progressive relaxation.

Two different stimulus (durational) referents, a red light (Wratten filter, No. 70) and a blue light (Wratten filter No. 49), were automatically timed by electronic interval timers. A high frequency buzzer of 0.02 sec. duration served as the get-ready signal. Each experimental subject, isolated in a sound-proof room, recorded his judgments of stimulus duration through manipulation of a contact key which was connected in circuit with the experimenter's chronoscope.

Three types of experimental schedules of stimulus duration were provided each estimator. An experimental schedule consisted of ten stimuli presented in sequential order for durational judgment. In addition to schedules consisting of ten stimuli with each stimulus in the sequence of ten having the same constant duration, two types of schedules (A-S-D and D-S-A) were introduced to determine the possible existence of illusory stimulus effects on time estimation. The A-S-D schedule consisted of the following durations in thousandths of a minute: 20-40-80-160-160-160-160-80-40-20. The A-S-D order was reversed in the D-S-A schedule. Not more than three schedules were given during any single experimental period.

The most important finding to emerge from this research on time estimation is the indeterminate nature of recall judgment in a sequence of judgments constituting a time schedule. By indeterminate, the authors do not mean non-causal, but rather unpredictable. It was impossible to predict the level of recall judgment from its antecedent judgment or judgments within a single schedule of time estimation. It was also impossible to forecast the pattern of response that characterized one schedule from the pattern of response that was characteristic of a previous similarly timed schedule. From an analysis of 2,000 time estimates in 200 schedules, the phenomenon of self-correction for undue overestimation or undue underestimation is clearly evident in the response patterns of every experimental subject tested. The range of overestimation or underestimation within a single schedule is the limit of cognizance of error in estimation for a given subject. The limit varies greatly not only at points within successive schedules for a given pilot or estimator, but also in a comparative evaluation of the points within the same schedules for all pilots as well as estimators. In the A-S-D and the D-S-A schedules, the descent, when plotted as a graph, is more rapid while the ascent is slower. The data from these latter types of schedules reveal that the expectation error tends to create underestimation in both the descending series and the ascending series. There is no conclusive evidence that any marked learning takes place in a single schedule when all statistical aspects relating to a single schedule are taken into account. There does not seem to be any formula or law that can be attributed to recall judgments of duration when the duration stimuli are presented in geometric order. The esthetic values and meanings of the two perceived colors in the duration stimuli may have played an unknown yet important role in time estimation. The relationship between the results of four critical schedules of time estimation and level of punctuality is approximately zero. There is no significant relationship between I.Q. level and accuracy in time estimation. So far as personality is concerned, there is merely a slight indication (not statistically significant) that one or more facets as extremes of personality structure may be associated with a greater degree of variability in time estimation.

To the variables which J.C. Loehlin recently (1959) assigned through factorial analysis to differences in time estimation, the experimenters of this investigation suggest adding tentatively the variable of muscular relaxation. Recall judgments of stimulus duration at the molecular level are notoriously inaccurate when motor rhythms are inhibited and the recall judgments are made under the influence of muscular relaxation. From the analyses of the data of this investigation, the tentative conclusion is drawn that progressive relaxation functions in a dominant way to interfere with the accuracy to estimate small units of time.

Appended to the report were 15 tables of statistics and a bibliography of 150 references.

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